Hydrogeomorphic (HGM) Functions in Appalachian Headwater and Perennial Streams

United States Army Corps of Engineers, ERDC

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Functions in Streams

1) Hydrology
2) Biogeochemical cycling
3) Habitat

Function 1
Hydrology

- Definition: the ability of a stream to dissipate energy associated with flow velocity and transport water downstream

Rationale

- Water transport and energy dissipation are fundamental functions of streams

- Affects the amount of sediment, organic matter and nutrients transported downstream

Effects of Hydrology

- Hydrologic alterations increase runoff and bank erosion, increasing sediment in channel
- Stream energy affects movement of materials downstream
- Excess sediment reduces habitat
  - Macroinvertebrates
  - Amphibians
  - Fish

Influences to Hydrology

- Natural conditions:
  - Climate
  - Geomorphic characteristics
  - Soil
- Anthropogenic alterations to watershed and riparian areas
  - Logging
  - Urban development
  - Agriculture
  - Grazing
  - Filling
  - Road building
  - Removal of large woody debris

Variables for Hydrology Function – Headwater Streams:

- Channel Substrate Embeddedness (V_{EMBED})
- Channel Substrate Size ($V_{SUBSTRATE}$)
- Channel Bank Erosion (V_{BERO})

Indicators of degradation in the channel

- Large Woody Debris (V_{LWD})
  - ► Affects flow and dissipation of stream energy
- Watershed Land-use (V_{WLUSE})
  - ► Affect timing and delivery of water to the channel

Hydrology Functional Capacity Index – Headwater Streams

$$FCI = \left\{ \frac{V_{WLUSE} + \left[\frac{V_{LWD} + \min\left(V_{SUBSTRATE}, V_{EMBED}, V_{BERO}\right)}{2} \right]}{2} \right\}$$

Water inputs from surrounding watershed

Large woody debris in the riparian/buffer zone

Channel indicators of hydrology

Variables for Hydrology Function – Perennial Streams:

- Streambank Stability ($V_{BANKSTAB}$)
  - If banks are not excessively eroded, channel flow, sediment transport and stream energy are likely appropriate
- Channel Substrate Size ($V_{SUBSTRATE}$)
  - Indicator of degradation in channel
- Channel Substrate Embeddedness (V_{EMBED})

Hydrology Functional Capacity Index – Perennial Streams

$$FCI = \left\{ \frac{V_{BANKSTAB} + \min\left(V_{EMBED}, V_{SUBSTRATE}\right)}{2} \right\}$$

Bank conditions

Hydrologic impacts to channel substrate

Function 2
Biogeochemistry

- Definition: ability of stream to retain and transform inorganic materials into organic forms and oxidize back into elemental forms through respiration and decomposition
- Includes activities of
  - Producers
  - Consumers
  - Decomposers

Rationale

- Supply of organic carbon maintains plant community
  - Primary productivity
  - Species composition
- Plant community provides food and structure for animal community
- Decomposers break down these organic materials, which reenter the nutrient cycle

Biogeochemistry: Processes

- 4 components of carbon cycle
  - Soil
  - Plants
  - Consumers (animals, fungi, bacteria)
  - Detritus
- Primary production sets the stage for all other processes

Influences to Biogeochemical Cycling

- Changes in vegetative cover
  - Amount of detritus
  - Temperature
  - Nutrients in soil
- Hydrologic alterations
  - Plant community
  - Nutrient delivery to channel
- Other alterations
  - Deposition of fill
  - Excavation
  - Fire

Variables for Biogeochemical Cycling Function – Headwater Streams:

- Channel Substrate Embeddedness (V_{EMBED})
- Large Woody Debris (V_{LWD})
- Riparian/Buffer Zone Tree Diameter (V_{TDBH})
- Riparian/Buffer Zone Soil Detritus ($V_{DETRITUS}$)
- Watershed Land-use (V_{WLUSE})
- Riparian/Buffer Zone Sapling/Shrub Density (V_{SSD})
- Riparian/Buffer Zone Herbaceous Cover (V_{HERB})

Only for streams with <20% canopy cover

Biogeochemical Cycling Functional Capacity Index – Headwater Streams

Streams with ≥20% canopy cover:

$$FCI = \left\{ V_{EMBED} \times \left[\frac{\left(\frac{V_{LWD} + V_{DETRITUS} + V_{TDBH}}{3} \right) + V_{WLUSE}}{2} \right] \right\}^{1/2}$$

Nutrient retention in channel

Nutrient inputs and long-term retention

Inputs from watershed

Streams with <20% canopy cover:

$$FCI = \left\{ V_{EMBED} \times \left[\frac{\left(\frac{V_{LWD} + V_{DETRITUS} + V_{SSD} + V_{HERB}}{4} \right) + V_{WLUSE}}{4} \right] \right\}^{1/2}$$

Variables for Biogeochemical Cycling Function – Perennial Streams:

- Channel Substrate Embeddedness (V_{EMBED})
- Channel Substrate Size ($V_{SUBSTRATE}$)
- Channel Canopy Cover ($V_{CCANOPY}$)
- Riparian/Buffer Zone Tree Density (V_{TDEN})

Biogeochemical Cycling Functional Capacity Index – Perennial Streams

$$FCI = \left\{ \frac{\min\left(V_{EMBED}, V_{SUBSTRATE}\right) + \min\left(V_{CCANOPY}, V_{TDEN}\right)}{2} \right\}$$

Nutrient retention in channel

Nutrient inputs and retention

Function 3: Habitat

Definition:

- The capacity of a stream ecosystem to provide critical life requisites to selected components of the vertebrate and invertebrate wildlife communities

Rationale:

- Species found in and around streams often are unique and not found in other ecosystems
- Responsible for secondary productivity and energy flows among trophic levels

Marshall Fantich ®

Impacts to the Wildlife Community Influence:

- Secondary productivity
- Carbon and nutrient export/transport
- Biological diversity including richness and evenness of the animal community itself and of the plant community
  - Patch level
  - Landscape level
- Trophic level processes

Impacts to Wildlife

- Hydrologic alteration
  - Scouring decreases habitat availability
  - Increases in fine sediment inhibit respiration
  - Turbidity slows primary production
  - Increased flows wash away fish eggs and young

Impacts to Wildlife (cont.)

- Channel vegetative cover
  - Water temperature and light levels
  - Detritus inputs to channel
    - Food availability
    - Breeding sites
    - Refugia
- Riparian and watershed vegetation
  - Amphibian habitat and dispersal
  - Erosion and sedimentation reduction

Variables for Habitat Function – Headwater Streams:

- Channel Canopy Cover ($V_{CCANOPY}$)
- Channel Substrate Embeddedness (V_{EMBED})
- Channel Substrate Size ($V_{SUBSTRATE}$)
- Channel Bank Erosion (V_{BERO})
- Large Woody Debris (V_{LWD})
- Riparian/Buffer Zone Tree Diameter (V_{TDBH})

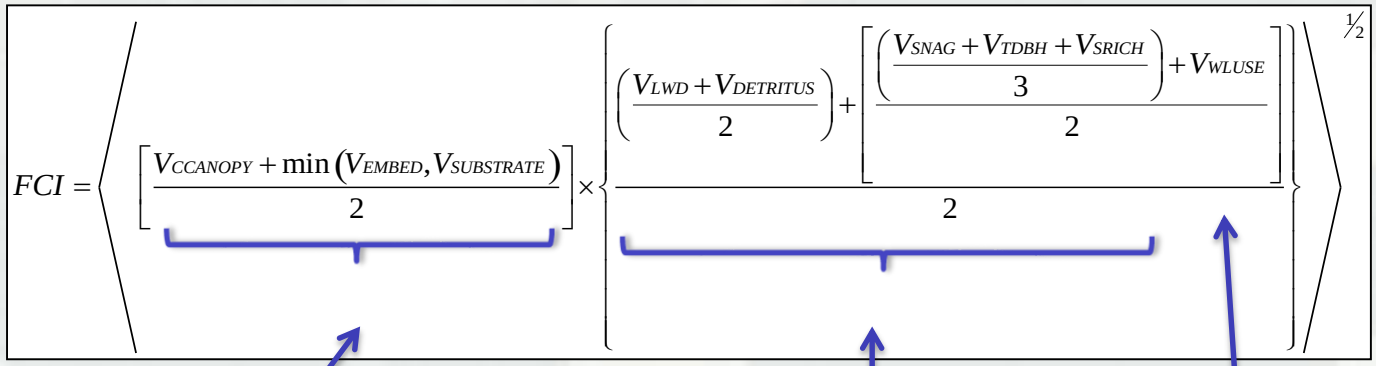
Variables for Habitat Function – Headwater Streams (cont.):

- Riparian/Buffer Zone Snag Density (V_{SNAG})
- Riparian/Buffer Zone Vegetation Species Richness (V_{SRICH})
- Riparian/Buffer Zone Soil Detritus ($V_{DETRITUS}$)
- Watershed Land-use (V_{WLUSE})
- Riparian/Buffer Zone Herbaceous Cover (V_{HERB})
- Riparian/Buffer Zone Sapling/Shrub Density (V_{SSD})

Only for streams with <20% canopy cover

Habitat Functional Capacity Index – Headwater Streams

Streams with ≥20% canopy cover:



Habitat Functional Capacity Index – Headwater Streams (cont.)

Streams with <20% canopy cover:

$$FCI = \left\langle \min\left(V_{EMBED}, V_{SUBSTRATE}\right) \times \left\{ \frac{\left(\frac{V_{LWD} + V_{DETRITUS}}{2}\right) + \left[\frac{\left(\frac{V_{SNAG} + V_{SSD} + V_{HERB} + V_{SRICH}}{6}\right) + V_{WLUSE}}{4}\right]}{2} \right\} \right\rangle^{1/2}$$

Channel characteristics

Riparian condition and seral stage

Watershed condition

Variables for Habitat Function – Perennial Streams:

- Channel Canopy Cover ($V_{CCANOPY}$)
- Channel Substrate Embeddedness (V_{EMBED})
- Channel Substrate Size ($V_{SUBSTRATE}$)
- Large Woody Debris (V_{LWD})
- Percent Forest (V_{FOREST})
- Riparian/Buffer Zone Tree Diameter (V_{TDBH})
- Coefficient of Conservatism (V_{CVALUE})

Habitat Functional Capacity Index – Headwater Streams

$$FCI = \left\{ \frac{V_{CANOPY} + \min(V_{EMBED}, V_{SUBSTRATE})}{2} \right\} \times \left\{ \frac{V_{LWD} + V_{FOREST} + \left(\frac{V_{DBH} + V_{CVALUE}}{2} \right)}{3} \right\}^{1/2}$$

Channel characteristics

Riparian and channel woody debris

Watershed condition

Riparian/buffer zone
- Species composition
- Seral stage

Questions?